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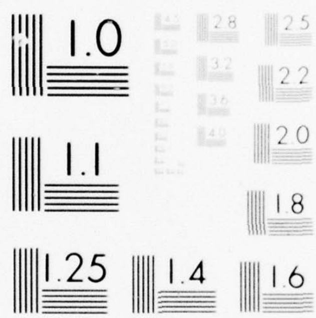

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(6) EXPERIMENTAL STUDY CONCERNING TASK DIFFICULTIES RESULTING FROM VARIOUS FACTORS OF AGE, ILLUMINANCE AND VISUAL PERFORMANCE.

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FOREWORD

The research discussed in this report was accomplished as part of the Maintainability Engineering Graduate Program conducted jointly by the USAMC Intern Training Center and Texas A&M University. As such, the ideas, concepts and results herein presented are those of the author and do not necessarily reflect approval or acceptance by the Department of the Army.

This report has been reviewed and is approved for release. For further information on this project, contact Mr. Ronald Higgins, Intern Training Center, Red River Army Depot, Texarkana, TX 75501.

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Maintainability Program

For the Commander

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13. ABSTRACT
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CHAPTER I

INTRODUCTION

The task of developing a lighting arrangement for improved production is of great concern to the engineer. Production of many items involve difficult visual tasks, which are often near the human visual limits.

Two basic approaches can be used in improving task visibility. The first approach can be to change the task to compensate for the lighting arrangement. The second approach can be to change the lighting level for performing the task. Changing the lighting level would seem more logical. By designing a suitable lighting system to improve the working conditions, the tasks performed could possibly be done more readily reducing manufacturing costs. The most obvious way to improve illumination, providing a suitable working environment, is by changing the light intensity to give the people concerned a comfortable atmosphere. A great deal of research has been directed towards experimenting with various light intensities and task brightness (1, 2, 5, 6, 7). In each case, the subjects were observed and their various task performances noted.

Present means of designing a suitable lighting arrangement have been developed through experimentation, past data and various design equations used to model a suitable lighting system. When designing a lighting arrangement, consideration should be given for the task involved and the employees. A drawback in most of the past design methods is that they did not take into consideration the physiology of the eye. The author designs an experiment to support his recommendations that the physiology of the eye be of vital consideration when designing a lighting arrangement.

Objective

The main objective of this paper is to show that the physiology of human vision is an essential factor in designing a lighting arrangement. By experimentation, the author shows that people in younger age brackets (20 - 30 yrs) perform better than others in older age brackets (40 - 50 yrs) under given conditions of illumination, and at some point when the light intensity is increased, the older subjects can perform on the same level as the younger workers. In this experimentation, three factors, illuminance, age group and task difficulty will be studied to observe the interrelationships of each.

The experiments employ the use of Landolt-ring charts (1). Landolt-rings are one of a series of incomplete rings or circles used in studying visual discrimination or acuity. Two types of Landolt-rings are used. One identified as Type A Landolt-ring is described as either a circle or a ring with a gap at one of eight positional points on the ring. Type B Landolt-ring is described in the same manner except Type B gaps will be harder to locate because they are hidden in the maze-like figure. The Landolt-rings are drawn to form a matrix. The size of the Landolt-rings either Type A or Type B are 3/4 inches in size. The experiments involved a subject identifying those rings in the matrix which have a break or a gap in a specified position. Each person was timed to compare results with other subjects. The subjects are grouped into two age brackets. The first bracket included people 30 years of age or less, while the second bracket included people 40 years of age or older. From these tests, it will be shown that older people perform just as well as younger people at high intensities of light, but as the illuminance decreases, the older people's performance levels drop off.

The remainder of the paper is divided into four chapters. The basics of eye anatomy and factors of concern when developing lighting system will be discussed in Chapter II. An explanation of what the experiments involve and how the test are run will be explained in Chapter III. Chapter IV will consist of experimental results and discussion. Finally, Chapter V gives a summary and recommendations for future studies.

CHAPTER II

REVIEW OF LITERATURE

Several factors that relate to performing visual tasks, and procedures that relate to studying the performance of subjects under various conditions and how their performances are related to their age are analyzed in the first half of this chapter. The second portion of the literature research describes the general physical description of the eye and its main functions.

Visual Task and Related Factors

The seeing tasks encountered in industry vary widely in what they require of the eyes for a successful accomplishment. The ability of the eye is dependent upon the visibility of the work, but modified by the visual capabilities of the human being himself. Task visibility is determined by its size, contrast, time of viewing, and brightness (3). There is an interrelationship involved between these factors when performing a task.

The first factor examined is the relationship of task performance and the size of the item worked on. As the size increases, visibility increases, and up to a certain point becomes easier. Also, with effective lighting the task performance becomes easier.

Time is another factor related to performing a given task. The speed with which a man can do his job is often a measure of his productiveness. If low brightness prevails, extra time will be needed to accomplish a particular task. If the brightness is increased, the time needed to perform a certain task will shorten. Also, tasks seen under high contrast and large size, generally require less time to perform.

Brightness is another factor which is very important, because it is a controllable factor. Brightness resulting from the light on the task and the surrounding visual field may be controlled within limits by varying the light intensity. Higher brightness levels can compensate for other factors involved in performing a visual task.

The most important factor which is the main theme of this paper is the problem of age and subnormal vision (2). Age is important, as a factor to be dealt with, and too often ignored while designing a suitable lighting arrangement. As aging progresses, a considerable number of changes occur in the eye. Significant changes are a gradual retreat of the near point and a considerable increase in the absorption and scattering of light in the eye itself and a reduction in the pupil diameter for a given adaptation level (2). Because of these aging factors, which hinder a person's productivity, consideration should be given to provide more illumination for the older workers compensating for his loss in visual capacity.

The pupil size is an important factor in the aging process. The size of the pupil decreases with age requiring higher brightness levels on an object to create the same degree of brightness on the retina of older eyes as obtained with younger eyes having larger pupils. It is possible to establish the brightness necessary to compensate for the loss of pupil size of an older person.

Accommodation is another consideration to be studied when designing a lighting system. Accommodation is the adjustment of the lens of the eye to fix upon objects at different distances. Age tends to flatten the lens permanently. The ability of an eye, old or young, normal or subnormal,

to accommodate is improved with increases in illumination. Other age factors that should be observed by illuminating engineers are visual acuity, speed of vision, ability to detect peripheral movements, ability to see under sudden changes of lighting and resistance to glare.

Several studies have shown the relationships between age, illuminance and visual performance. Boyce (1) showed that age is an important intervening variable in the relationship between illuminance and visual performance. His study involved comparing results by people 30 years of age and older. The results came from various experiments using Landolt-ring charts. The conclusion was that age is a factor when performing a visual task. Boyce produced other papers that supported this concept (2).

Productivity is one by-product of the relationship between age, illuminance and visual performance. Increased labor, material, energy, and capital costs have brought increased emphasis on improving worker productivity in office and industry. While it has long been known that there is a positive relationship of lighting to productivity, several recent studies document the quantitative effects.

One investigation by Dr. Philip Hugh studied the effects of room illumination at 150 foot candles and 50 foot candles on keypunch operators (5). The study was conducted over a five week period. Weeks 1, 3, and 5 were at 150 footcandles and weeks 2 and 4 were at 50 foot candles. The results showed a 12 percent overall reduction in the number of keypunch cards punched by the operators when working under the reduced illumination (50 FC). Another study concerned 500 clerical accounting employees in a Social Security Building. The lighting was reduced from 100 foot candles to 50 foot candles. Productivity dropped 30 percent over a six week span (6).

The Illuminating Engineering Society Recommended Practice for Office Lighting is shown in Table 1. The illumination levels are for young adults with normal vision and better than 20/30 corrected vision. For efficient use and to achieve maximum productivity, the illumination levels should vary accordingly to the personnel involved.

Physical Features of the Eye

The structure of the eye is shown in Figure 1. When the light strikes the eye it must first pass through the cornea. Because of its curvature, there is a considerable refraction of light rays when entering the cornea. Next, the rays enter the crystalline lens of the eye. The lens has an elastic capsule which tends to flatten out or form a spherical shape depending on whether an object is near by or far away. The flexibility is due to the sclera or outer portion of the eye and is transmitted to the lens by the ciliary muscles. After light penetrates the lens, an image is formed on the retina. There, a chemical process takes place in the rods and cones and the image is received by the nerve fiber and sent to the brain. The cones are capable of color discrimination and are the receptors most requently used in everyday visual functions. The rods, which lack color discrimination, are more sensitive than cones and are more active at low levels of luminance.

TABLE 1

Recommended Practice for Office Lighting

Office Area	Footcandle on Tasks
Drafting Rooms:	
a.) Detailed drafting & designing.	200
b.) Rough layout drafting.	150
Accounting Offices:	
a.) Auditing, tabulating, bookkeeping business machine operation, computer operation.	150
General Offices:	
a.) Reading poor reproductions, business machine operation, computer operation.	150
b.) Reading handwriting in hand pencil or on poor paper, active filing, mail sorting.	100
c.) Reading handwriting in ink or medium pencil on good quality paper, intermittent filing.	70
Private Offices:	
a.) Reading poor reporduction, business machine operation.	150
b.) Reading handwriting in hand pencil or on poor paper reading fair reproductions.	100
c.) Reading handwriting in ink on good quality paper.	70
d.) Reading high contrast or well-printed materials.	30
e.) Conferring or interviewing.	30
Conference Rooms:	
a.) Critical seeing tasks.	100
b.) Conferring.	30
c.) Note taking during projection.	30
Washrooms:	30
Elevators, Escalators	20

TABLE 1 (con't)

Office Area	Footcandles on Tasks
Stairways	20
Cooridors	20

Illuminating Engineering Society (3)

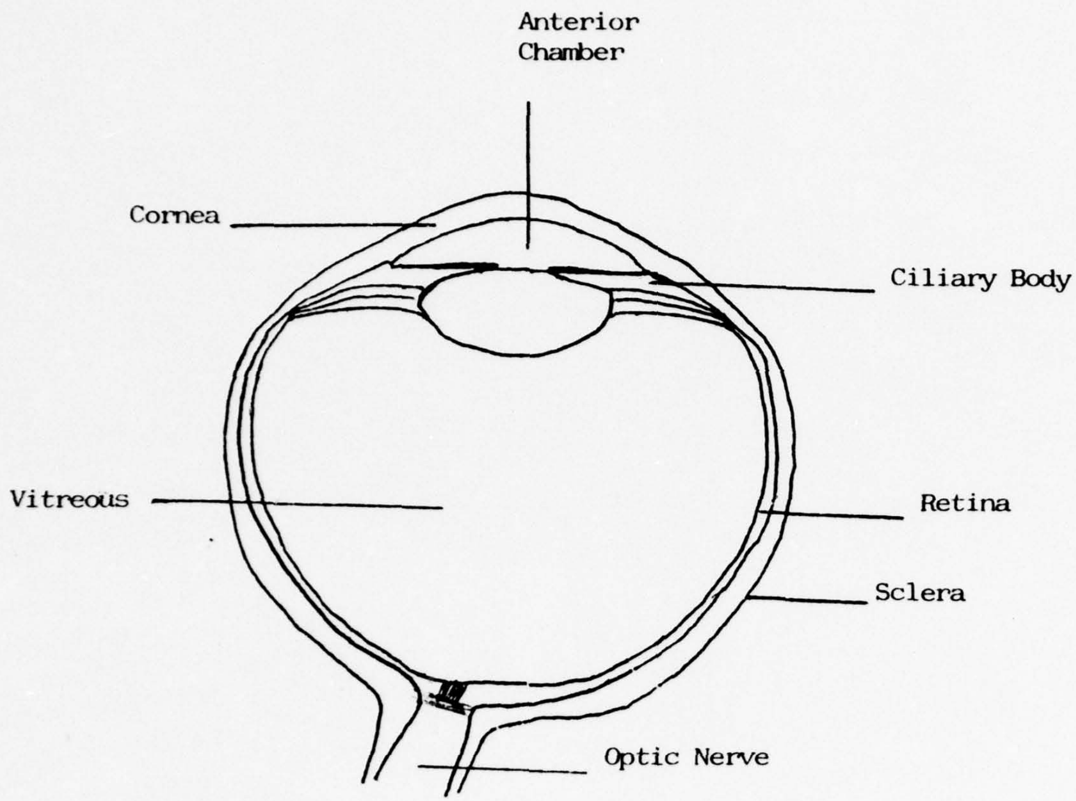


FIGURE I: THE EYE

CHAPTER III

EXPERIMENTAL CONDITIONS

Objective

The objectives of this experiment is to investigate the performance levels of various subjects under different intensities of light, to determine if age, illuminance and task difficulty were related. One color (amber) of illumination was selected and the visual performances of eight subjects were recorded. Two 150 watt white frosted in candescent light bulbs were used in the experiments. The light intensity for the frosted white color bulbs was varied between two levels. The two levels used were 10 foot candles and 175 foot candles. The subjects in the experiments were divided into two age brackets. The first bracket consists of people 30 years of age and younger, while the second group was made up of people 40 years of age and older. Task scores, obtained from various Landolt-ring charts, were used to evaluate visual performance.

Physical Setup

The experiments were conducted in a 10 by 10 foot darkened room. The subjects were seated at a table to perform their tasks. For each experiment a particular Landolt-ring chart was placed on the table and measurements of the time taken to perform a certain task were recorded. Illumination of the task was provided by placing two light sources in front and above the subjects. The conditions were such that a comfortable working area was produced.

Environmental Conditions

The major environmental condition of concern in these experiments is illumination of the working area. Once the experiments were started,

precautions were taken to make sure no additional light would occur.

As previously mentioned, the experiments were conducted under two illumination intensity levels. The lighting for the working area was controlled by using a dimmer switch so that each intensity level could be controlled. The light sources used in these experiments were General Electric incandescant light bulbs. The frosted incandescent light bulbs were rated at 150 watts.

The two illumination intensity levels were measured using General Electric foot-candle meter. This meter can measure light intensities from 0 ft-c (foot-candles) to 1000 ft-c. The measurements for the various light intensities were taken at the point where the charts would be placed to perform the task. The levels of illumination used in the experiments were set at 10 and 175 ft-c. The experiments were performed in a room where the noise levels would not effect the concentration of the subjects performing their tasks.

Subject Selected

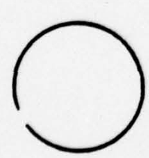
The selection of subjects was an important part in preparing the experiments. A total of eight people were chosen. Four of the subjects were of the age 30 or less while the other four were 40 years of age and older. No one in the groups was younger than 20 or older than 50. Each group contained two male and two female members. Only one person, who was in the younger age group, had attended college. Three of the subjects had normal vision while the remaining five required the use of corrective lenses, to aid their vision.

Task Design

The type of task was selected so as to prove that older people require a longer time to complete a task when compared with younger people under certain illumination levels. Tasks chosen for the experiments were Landolt-ring charts which included either Type A or Type B Landolt-rings.

The Type A rings as explained before are just circles or rings 3/4 inches in diameter with gaps, one gap on each rings, at one of eight positional points on the rings. Type B Landolt-rings are of the same description as Type A, but the gaps on the rings are hidden in the maze-like figure. The gap for the 3/4 inch rings is approximately 1/8 inch in length. All charts are made up of either all Type A or Type B rings in a 7 by 7 matrix, note Figure 2 for the types of Landolt-rings used in the charts.

TYPE A



TYPE B

Figure 2

The considerations to be noted in designing these charts and the lighting arrangements were, first, to observe the difficulty the older subjects would have in identifying the particular rings at low illumination. Next, to compare the results of the tasks performed by the groups under varied illuminations in the experiments. Finally, the design of the experiments were to show that aging of the eye faculties can have an effect on visual performance.

Test Procedure

The subjects in each group were instructed in the proper manner of task performance by the experimeter the day before their test were recorded. In the preparatory sessions each subject performed several Landolt-ring charts under normal lighting conditions and then were told how the lighting levels would be changed for each experiment to be recorded the next day.

Before the experiments were started, a Table was constructed representing chart type, illumination and group type of 32 tests for randomization purposes. Complete randomization ensured the averaging out of any effects which might be correlated with the time of the experiments (4). A flip of a coin was used to determine the order of all 32 runs. For each run, three flips were made to determine chart type (A or B), Illumination (10 ft-c or 175 ft-c) and Age Group. Heads represented either chart type (A Landolt-ring), or low illumination (10 ft-c) or Age Group (young age bracket). Tails represented the other three alternatives. A typical example for a coin flip would be HTT which represents a run of chart type A(H), high Illumination (T) and older age group (T). It should be noted that some of the conditions may be repeated (example HHH and HHH). The only restriction on complete randomization is once four repeated measures

have occurred no more will be run using those same conditions.

Each test, using the Landolt-ring charts, required that the subjects choose six circles and six rings, containing a gap located at the right center, positioned randomly in the 7 by 7 matrix of the Landolt-rings. In each case the specified rings and circles were located in randomly chosen positions. This would eliminate the possibility of a subject memorizing the positions of the rings after repeated test. During the test the subjects would mark-out the specific rings with their pen and would raise their pen when finished with the chart.

The experimenter at all times made the appropriate illumination level changes, and kept a record of each subject's task times for each experiment.

CHAPTER IV

EXPERIMENTAL RESULTS AND DISCUSSION

The experiments are designed to study the effects of several factors on the visual requirements for task performance. The main objective of the study was to determine what effects, if any, illumination, age, and chart design had on visual performance. The illumination levels for the experiments were set at 10 ft-c and 175 ft-c. Two age categories were used in the experiments. Also, two types of charts were used. There are, then, two fixed levels for each of the three-factors or eight experimental conditions (2^3). This is called a 2^3 factorial experiment since both levels of each of the three factors are being combined with both levels of all other factors.

It was decided to choose four people for each group, under each of the eight conditions, making a total of 32 runs. To randomize the experiments the illumination levels, chart type and subjects were picked at random.

To determine what effects the three factors may have on visual performance, a statistical analysis was performed on the data obtained in the experiments. The analysis indicates what factors were significant in the experiments.

The three factors, illumination, chart type, and subjects were involved in the experiment. The intensity levels and chart type were predetermined before the experiments, therefore, represent fixed factors. The subjects in the experiments, however, were picked at random and represent a small sample of all possible subjects, thus representing a random factor. The mathematical model of this experiment is thus a three factor mixed model.

The mathematical model for this experiment and design is:

$$Yijkm = \mu + Ci + Ij + CIij + Gk + CGik + IGjk + CIGijk + Em(ijk)$$

where Yijkm represent the measured variable μ a common effect in all observations. This is the true mean of the population from which all the data came. Ci represents the type of chart where i = 1,2. Ij represents the illumination with j = 1,2 and Gk the group type assigning k = 1,2. Em(ijk) is the random error in the experiment with m = 1,2,3,4. The other terms represent the interactions between the main factors C, I and G. Table 2 presents the calculations for arriving at the sum of the squares (SS), for the analysis of variance (ANOVA) of a three-factor factorial with n replications per cell.

The analysis of this experiment consist of collecting 32 items of data indicated in Table 3 taken in a completely randomized manner. The units of measurement are in seconds. The experiments and the mathematical model suggest a three-way analysis of variance (ANOVA) which yield the final results in Table 4.

To interpret the results in Table 4, seven different hypotheses may be tested:

H1: Ci = o for all i (no chart effect)

H2: Ij = o for all j (no illuminance effect)

H3: Gk = o for all k (no group effect)

H4: CIij = o for all i and j (no C X I interaction effect)

H5: CGij = o for all i and k)no C X G interaction effect)

H6: IGjk = o for all j and k (no I X G interaction effect)

H7: CIGijk = o for all i, j and k (no C X I X G interaction effect)

The proper test statistic is the F statistic with 1 and 24 degrees of freedom. At the 5 percent significance level ($\alpha = 0.05$) the critical region of F is 4.26. Comparing each mean square with the error mean square indicates that all but two hypothesis can be rejected: I X G and C X I X G have no effect on the experiment.

The results of the F test show a significance among all the individual in performing the experiments. Subject variability is highly significance as expected for the comparisons between age groupings. The reason the three factors are significant is that the hypothesis made at the beginning of the experiments stated that these three factors would have no effect on the outcome of the experiments. From the results this was proven false. The results showed that the only factors that proved true from the typothesis were the interaction between illuminance and group type (I X G) and the interaction between chart type, illuminance, and age groupings (C X I X G).

TABLE 2

ANOVA for a Three-Factor Factorial With n Replications Per Cell

Source	df	ss	ms
Factor C	a-1	SSC	Each ss is divided by its df
Factor I	b-1	SSI	
Factor G	c-1	SSG	
Interaction C X I	(a-1)(b-1)	SSCI	
Interaction C X G	(a-1)(c-1)	SSCG	
Interaction I X G	(b-1)(c-1)	SSIG	
Interaction C X I X G	(a-1)(b-1)(c-1)	SSCIG	
E(error)	abc(n-1)	SST	
TOTAL	abcn	SST	

SS (Valves)

$$SST = \sum_{i}^{a} \sum_{j}^{b} \sum_{k}^{c} \sum_{m}^{n} Y_{ijkm}^2 - \frac{Y^2}{abcn}$$

$$SSC = \frac{\sum_{i}^{a} Y_{i...}^2}{bcn} - \frac{Y_{....}^2}{abcn}$$

$$SSI = \frac{\sum_{j}^{b} Y_{..k.}^2}{abn} - \frac{Y_{....}^2}{abcn}$$

$$SSG = \sum_{k}^{c} Y_{..k.}^2 - \frac{Y_{....}^2}{abcn}$$

$$SSCI = \sum_{i}^{a} \sum_{j}^{b} \frac{Y_{i.k.}^2}{cn} - SSC - SSI + \frac{Y_{....}^2}{abcn}$$

$$SSCG = \sum_{i}^{a} \sum_{k}^{c} \frac{Y_{i.k.}^2}{bn} - SSI - SSG + \frac{Y_{....}^2}{abcn}$$

$$SSIG = \sum_{j}^{b} \sum_{k}^{c} \frac{Y_{.jk.}^2}{an} - SSI - SSG + \frac{Y_{....}^2}{abcn}$$

$$SSCIG = \sum_{i}^{a} \sum_{j}^{b} \sum_{k}^{c} \frac{Y_{ijk.}}{n} - SSC - SSI - SSG - SSCI$$
$$- SSCG - SSIG - \frac{Y_{....}^2}{abcn}$$

SS ERROR = SST - SSC - SSI - SSG - SSCI - SSCG - SSIG - SSCIG

TABLE 3

A Test of Visual Performance

	Group I (30)		Group II (40)	
	Illuminance(ft-c)		Illuminance(ft-c)	
CHART	10	175	10	175
	35.0	24.2	35.3	25.2
TYPE A	34.2	23.4	37.1	27.2
	35.1	25.3	37.3	26.5
	37.2	26.0	36.1	29.0
	40.3	26.1	39.0	29.2
TYPE B	39.1	25.2	45.1	30.6
	42.1	26.9	47.2	32.5
	37.3	28.1	44.6	30.7

TABLE 4

ANOVA for a Three-Factor

Factorial for the Experimental

Data

Source	df	SS	MS	EMC
Ci	1	152.69	153.69*	$\sigma^2_\varepsilon + 8\sigma^2_{CG} + 16\phi_C$
Ij	1	1079.96	1079.96*	$\sigma^2_\varepsilon + 8\sigma^2_{IG} + 16\phi_I$
Gk	1	69.33	69.33*	$\sigma^2_\varepsilon + 16\sigma_G$
CIij	1	19.38	19.38*	$\sigma^2_\varepsilon + 4\sigma^2_{CIG} + 8\phi_{CI}$
IGik	1	13.10	13.10*	$\sigma^2_\varepsilon + 8\sigma^2_{CG}$
IGjk	1	.58	.58	$\sigma^2_\varepsilon + 8\sigma^2_{IG}$
CIGijk	1	.83	.83	$\sigma^2_\varepsilon + 4\sigma^2_{IG}$
Em(igk)	24	78.12	3.26	σ^2_ε
TOTAL	31	1413.99		

*Significance is indicated at the 5 percent level.

TABLE 5

Adjusted Experimental Data

For Calculating Sum of Squares

(Table 3 Entries Minus 33.07)

	Group I (30)		Group II (40)		
	Illuminance(ft-c)		Illuminance(ft-c)		
	1.93	-8.87	2.23	-7.87	
	1.13	-9.67	4.03	-5.87	
TYPE A	2.03	-7.77	4.23	-6.57	-35.02
	4.13	-7.07	3.03	-4.07	
	9.22	-33.38	13.52	-24.38	
	7.23	-6.97	5.93	-3.87	
	6.03	-7.87	12.03	-2.47	
TYPE B	9.03	-6.17	14.13	-0.57	34.88
	4.23	-4.97	11.53	-2.37	
	26.52	-25.98	43.62	-9.28	
	35.74	-59.36	57.14	-33.66	-.14

CHAPTER V

SUMMARY AND RECOMMENDATIONS

Summary

There is evidence to conclude that when an engineer designs a lighting system he should take into consideration the aging factors of the eye for the workers concerned. From the statistical analysis the factors of illuminance, age, and chart task are of significant importance when designing a lighting system.

Recommendations

Additional experiments with more complicated experimental procedures should be performed to show more detailed effects of the aging processes in the eye. Some of the task to perform are the self-paced Landolt-ring charts, paced Landolt-ring tasks, tracking task and conveyor tasks. Experimenting with greater intensities of light could also be a factor in future experiments.

By dividing the subjects tested into smaller age groupings, ex: 25, 30, 35, 40..., experiments could be run to compare and determine at what age the visual processes starts to decline. Choosing subjects who either all wear corrective lens or who all have 20/20 vision, in similar age groupings, for experimental purposes would be interesting to observe and to compare their results. Also, designing different task charts for experimenting could influence task times.

A simulation model of the eye could also be an important tool in developing a lighting system. One such model has been developed by John Spencer (7). The model represents the interaction between the pupil and retina systems. Spencer's model simulates the decomposition process

of rhodopsin in the eye. By simulating the input signal, visual signed and the pupillary control mechanism of the eye comparisons of subjects can be made by observing their rate of decomposition of rhodopsin and pupil variation due to a predetermined input signal.

The main draw-back in this particular model is that it simulates only one cell of the eye. Hence, to acquire a more accurate model a multicelled design should be incorporated. Also, Spencer's model is a analog simulation for a one cell model, thus, to simulate a multi-celled model the program should be converted to fortran to efficiently handle the system.

In conclusion, lighting working areas for productive results is an important problem which at the present time has not been developed to its fullest potential but with today's increasing technology, new methods will be found for designing lighting arrangements.

LIST OF REFERENCES

1. Boyce, P.R., "Illuminance, Difficulty, Complexity and Visual Performance", Lighting Research and Technology, Vol. 6, No. 4, Pages 222 - 226, 1974.

2. Boyce, P.B., "Age Illuminance, Visual Performance and Preference", Lighting Research and Technology, Vol. 5, No. 3, Pages 125 - 139, 1973.

3. Illuminating Engineering Society, American National Standard Practice for Industrial Lighting, June 26, 1970.

4. Hicks, Charles R., Fundamental Concepts in the Design of Experiments, Holt, Rinehart and Winston, Incl., New York, 1973.

5. Hugh P.C., "Productivity of Keypunch Operators", General Electric Company, Nela Park, Cleveland, Ohio.

6. Hugh, P.C., "Studies Show Lighting Affects Productivity", Electrical World, June 15, 1975.

7. Spencer, John R., "Pupil-Retina Interaction: An Analog Eye Response Model", Master's Thesis Texas A&M University, December, 1972.

APPENDIX

APPENDIX

CALCULATIONS FOR ANALYSIS OF VARIANCE

Calculate the Sum of Squares

$$SST = \sum_{i}^{a} \sum_{j}^{b} \sum_{k}^{c} \sum_{m}^{n} Y_{ijkm}^{2} - \frac{Y_{....}^{2}}{abcn}$$

$$SST = 1413.99 - \frac{(-14)^{2}}{32} = \underline{1413.99}$$

$$SSC = \frac{\sum_{i}^{a} Y_{i...}^{2}}{bcn} - \frac{Y_{....}^{2}}{abcn}$$

$$SSC = \frac{(-35.02)^{2} + (34.88)^{2}}{16} - \frac{(=14)^{2}}{32} = 152.69$$

$$SSI = \frac{\sum_{j}^{b} Y_{.j..}^{2}}{acn} - \frac{Y_{....}^{2}}{abcn}$$

$$SSI = \frac{(92.88)^{2} + (-93.02)^{2}}{16} - \frac{(-.14)^{2}}{32} = \underline{1079.96}$$

$$SSG = \frac{\sum_{k}^{c} Y_{..k.}^{2}}{abn} - \frac{Y_{....}^{2}}{abcn}$$

$$SSG = \frac{(23.62)^{2} + (23.48)^{2}}{16} - \frac{(-14)}{32} = \underline{69.33}$$

$$SSCI = \sum_{i}^{a} \sum_{j}^{b} \frac{Y_{ij..}^{2}}{cn} - SSC - SSI - \frac{Y_{....}^{2}}{abcn}$$

$$SSCI = \frac{(22.74)^{2} + (-57.76)^{2} + (70.14)^{2} + (-35.26)^{2}}{8} - \frac{(-.14)^{2}}{32}$$

$$-1079.96 - 152.69 = \underline{19.38}$$

Calculate Sum of Squares

$$SSCG = \sum_{i}^{a}\sum_{k}^{c} \frac{Y_{i.k.}^{2}}{bn} - SSC - SSG - \frac{Y_{....}^{2}}{abcn}$$

$$SSCG = \frac{(-24.16)^2 + (.54)^2 + (10.85)^2 + (34.34)^2}{8} - \frac{(-.14)^2}{32}$$

$$-69.33 - 152.69 = \underline{13.10}$$

$$SSIG = \sum_{j}^{b}\sum_{k}^{c} \frac{Y_{.jk.}^{2}}{an} - SSI - SSG - \frac{Y_{....}^{2}}{abcn}$$

$$SSIG = \frac{(35.74)^2 + (-59.36)^2 + (57.14)^2 + (-33.66)^2}{8} - \frac{(-.14)^2}{32}$$

$$-69.33 - 1079.96 = \underline{.58}$$

$$SSCIG = \sum_{i}^{a}\sum_{j}^{b}\sum_{k}^{c} \frac{Y_{ijk.}}{n} - SSC - SSI - SSG - SSCI - SSCG$$

$$-SSCG - SSIG - \frac{Y_{....}^{2}}{abcn}$$

$$SSCIG = \frac{(9.22)^2 + (-33.38)^2 + (13.52)^2 + (24.38)^2 + (26.52)^2 + (-25.98) +}{4}$$

$$\text{(con't)}\ \frac{(43.62)^2 + (9.28)^2}{4}$$

$$-\frac{(-.14)^2}{32} - 69.33 - 1079.96 - 152.69 - .58 - 13.10 - 19.38 = \underline{.83}$$

SS ERROR = SST - SSC - SSI - SSG - SSCI - SSCG - SSIG - SSCIG

SS ERROR = 1413.99 - 1079.96 - 152.69 - 69.33 - 13.10 - 19.38

-.58 -.83 = 78.12

TABLE 6

Estimated Mean Square for the Experimental Data

	2	2	2	4	
	F	F	R	R	
	i	j	k	m	EMC
Ci	0	2	2	4	$\sigma_{\varepsilon}^2 + 8\sigma^2_{CG} + 16\phi_C$
Ij	2	0	2	4	$\sigma_{\varepsilon}^2 + 8\sigma^2_{IG} + 16\phi_I$
Gk	2	2	1	4	$\sigma_{\varepsilon}^2 + 16\sigma_G$
CIij	0	0	2	4	$\sigma_{\varepsilon}^2 + 4\sigma^2_{CIG} + 8\phi_{CI}$
CGik	0	2	1	4	$\sigma_{\varepsilon}^2 + 8\sigma^2_{CG}$
IGjk	2	0	1	4	$\sigma_{\varepsilon}^2 + 8\sigma^2_{IG}$
CIGijk	0	0	1	4	$\sigma_{\varepsilon}^2 + 4\sigma^2_{IG}$
Em(ijk)	1	1	1	1	σ_{ε}^2

F - Fixed Factor

R - Random Factor

Hicks (4)